Proceedings Paper:

Marvin, Andy orcid.org/0000-0003-2590-5335, Flintoft, Ian Daivd orcid.org/0000-0003-3153-8447, Dawson, John Frederick orcid.org/0000-0003-4537-9977 et al. (6 more authors) (2016) Enclosure shielding assessment using surrogate contents fabricated from radio absorbing material. In: 2016 Asia-Pacific Symposium on Electromagnetic Compatibility (APEMC2016). APEMC: Asia-Pacific International Symposium on Electromagnetic Compatibility, 18-21 May 2016 , CHN , pp. 994-996.

https://doi.org/10.1109/APEMC.2016.7522926

Author post-print

Enclosure Shielding Assessment Using Surrogate Contents Fabricated From Radio Absorbing Material

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Published in the Proceedings of the 7th Asia-Pacific International Symposium on Electromagnetic Compatibility & Signal Integrity and Technical Exhibition (APEMC 2016), Shenzhen, China, pp. 994-996, 18-21 May, 2016.

Accepted for publication 29/01/2016

DOI: [10.1109/APEMC.2016.7522926](https://doi.org/10.1109/APEMC.2016.7522926)

URL: http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=7522926

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***Abstract*—The electromagnetic environment inside an equipment enclosure at high frequencies is strongly dependent on the absorption of energy by the contents. This effect is neglected by current shielding measurement standards. Here we extended the concept of shielding measurements using surrogate "representative contents" proposed at lower frequencies into the regime were the enclosure is electrically large. We demonstrate how a surrogate fabricated from radio absorbing material can be made to give the same overall absorption as a real printed circuit board and hence produce the same internal environment inside an enclosure during a shielding measurement.**

Keywords—enclosure shielding, absorption cross-section, reverberation chamber

I. Introduction

Absorption in an enclosure's contents directly impacts on the level of the electromagnetic fields seen by circuits inside the enclosure [1], [2]. The current IEEE299 enclosure shielding standard has an informative annex regarding contents [3]; however, no standardised approach to dealing with the effects of contents at high frequencies has been developed. This paper reports an enclosure shielding effectiveness (SE) methodology using surrogate representative contents that attempts to fill this gap.

For electrically large enclosures, statistical methods are essential so our approach is based upon power balance techniques and reverberation chamber (RC) measurements [4],[5]. The average absorption-cross section (ACS) is used to match the absorption in the surrogate contents to the real contents, i.e. printed circuit board (PCBs) [6][7]. In Section II we outline how a surrogate can be designed. The measurement methodology for ACS and SE are described in Section III and the results of the measurement are given in Section IV. We conclude in Section V.

II. Design of the Surrogate PCB

A PCB from an Information and Communication Technology (ICT) enclosure is shown in the top part of Fig. 1. It will absorb electromagnetic power from its environment by a number of mechanisms including into the substrate losses, into the component packaging materials and into the circuit loads at the end of transmission lines.

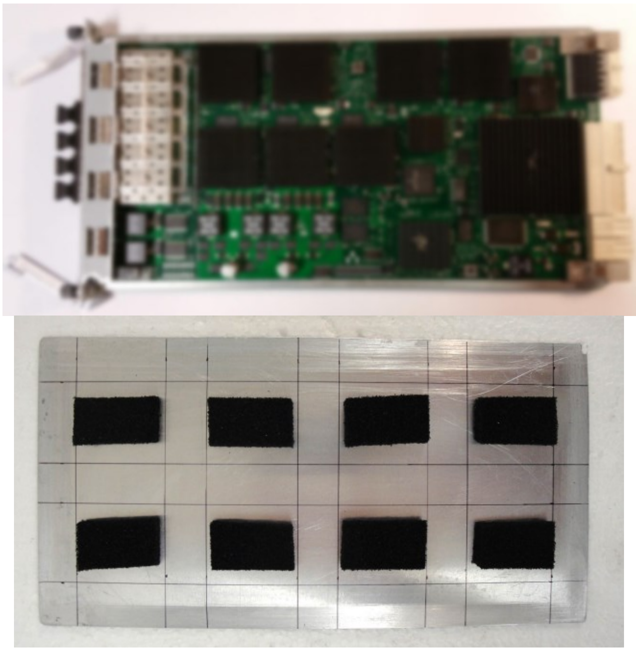

Fig. 1. Photograph of the real PCB (top) and surroage (bottom).

The absorption will be distributed over the area of the PCB [8]. We attempted to replicate the average absorption using a number of blocks of radio absorbing material (RAM) arranged on top of a metal plate as shown in the bottom part of Fig. 1.

The RAM thickness has to be a compromise between the available space between the PCBs in the enclosure (20 mm) and the fact that the absorption in the RAM falls at lower frequencies when it is made thinner. Using Eccosorb LS22 material [9] a thickness of 9.5 mm was found to give a suitable balance between these effects. Once the thickness is determined the overall absorption in the surrogate is determined by the surface area coverage factor. Using the RAM manufacturer's complex permittivity data and a multilayer laminate reflection and transmission model the average ACS of the RAM blocks can be estimated [5]. This suggested, anticipating the measured ACS of the real PCB shown in Section IV, that a coverage factor about 20 % would achieve the desired match to the real PCB.

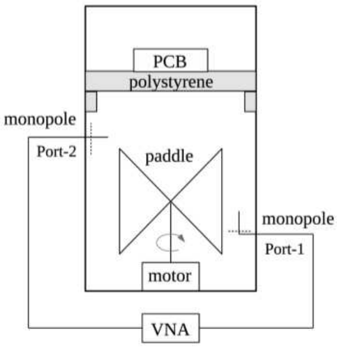

Fig. 2. Configuration for ACS measurement.

TABLE I. MEASUREMENT PARAMETERS.

Parameter	Value
Start frequency	2 GHz
Stop frequency	20 GHz
Number of points	10,001
Frequency resolution	1.9 MHz
Sweep time	2.7 s
Number of paddle positions	100
Frequency tuning bandwidth	100 MHz

III. MEASUREMENT METHODOLOGY

A. Absorption cross-section

The average ACS of an object can be measured in a reverberation chamber using the setup shown in Fig. 2. The method is based on the approach of Carlberg et al. [10],[7] and the details of the implementation of the measurement used here can be found in [6]. The average ACS is determined from the average insertion loss of the chamber with and without the object-under-test present, $\langle IL\rangle_{\text{loaded}}$ and $\langle IL\rangle_{\text{unloaded}}$ respectively, using

$$\left\langle \sigma^{a}_{\text{OUT}} \right\rangle = \eta^{T}_{1}\eta^{T}_{2}\frac{\lambda^{2}}{8\pi}\left(\left\langle IL\right\rangle_{\text{loaded}} - \left\langle IL\right\rangle_{\text{unloaded}}\right), \tag{1}$$

where λ is the wavelength and $\eta^{T}_{1/2}$ are the total antenna efficiencies of the two monopole antennas. $\langle\ldots\rangle$ denotes an average over paddle positions and a frequency stirring bandwidth. The insertion loss was measured using a vector network analyser (VNA) with the parameters given in Table I. For relative ACS measurements the antennas efficiencies do not need to be known explicitly. The ACS of both the real PCB and surrogate were measured using this method.

B. Shielding effectiveness

The measurement configuration for SE in an RC is shown in Fig. 3. In an RC the SE is usually defined as a ratio of the insertion losses between a transmitting antenna and two identical probe antennas – a reference probe in the RC, $\langle IL\rangle_{\text{REF}}$, and another probe in the enclosure, $\langle IL\rangle_{\text{enc}}$ [5]:

$$SE = \frac{\left\langle IL_{\text{REF}}\right\rangle}{\left\langle IL_{\text{enc}}\right\rangle} = 1 + \frac{\left\langle \sigma^{a}_{\text{enc}}\right\rangle}{\left\langle \sigma^{t}\right\rangle} \tag{2}$$

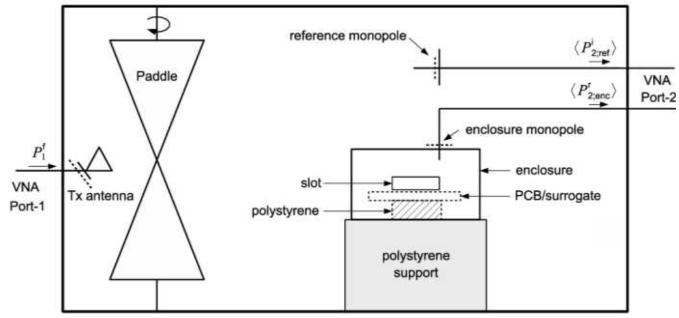

Fig. 3. Configuration for shielding effectiveness measurement.

Fig. 4. Photograph of the measurement setup.

The second relationship relates the SE to the average total ACS of the inside of the enclosure, $\langle\sigma^{a}_{\text{enc}}\rangle$, and the average total transmission cross-section of the enclosure, $\langle\sigma^{t}\rangle$ [4].

The enclosure used for these measurements had dimensions 0.6 m×0.5 m×0.3 m and had a single rectangular aperture of dimensions 140 mm×40 mm centred on one face. The PCB or surrogate was placed on a block of polystyrene in the centre of the enclosure, well away from the walls. The insertions losses were again measured using a VNA with the parameters given in Table I. Note that we do not use mechanical stirring inside the enclosure, but rely on frequency stirring alone to vary the boundary conditions on the internal fields. A photograph of the experimental arrangement is shown in Fig. 4. The SE of the empty enclosure and the enclosure populated with the real PCB and surrogate were measured.

IV. RESULTS

The measured ACSs of the PCB and the surrogate are shown in Fig. 5. The ACS of the PCB has a relatively flat profile in the range 3-7×10^{-3} m^2. It is maximal at 3-4 GHz and falls slowly at higher frequencies. The ACS of the surrogate rises slowly from about 2×10^{-3} m^2 at 2 GHz, reaching a plateau of about 4×10^{-3} m^2 at 6 GHz. On average over the frequency band measured the ACS of the surrogate matches that of the real PCB.

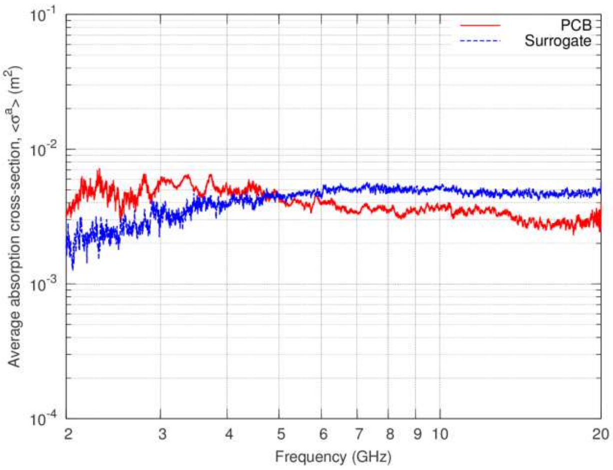

Fig. 5. Measured ACS of the PCB and representative contents.

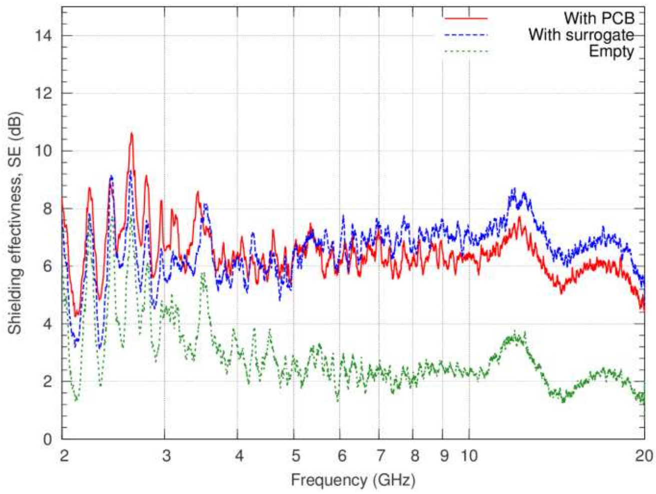

Fig. 6. Measured shielding effectiveness of the enclosure when empty and when contaning the PCB and representative contents.

The measured SEs of the enclosure with different contents are shown in Fig. 6. When empty the SE of the enclosure is only 2-4 dB over most of the frequency range. At low frequencies, below about 4 GHz, the enclosure has a limited number of modes and therefore the internal field has limited statistical variation. Above 4 GHz the frequency stirring of the internal modes is sufficient to generate a relative smooth average response.

With the PCB present in the enclosure the SE increases to around 7-8 dB. This clearly shows the importance of the enclosure contents in determining the internal electromagnetic environment inside an equipment enclosure. Some of the same features as in the empty case are still present in the spectrum; however, there is now a steadily increasing trend in the overall level of the SE. The SE with the surrogate is very similar to that with the real PCB; from (2) the slightly higher SE with the surrogate at higher frequencies is directly attributed to the slightly higher ACS of the surrogate.

V. CONCLUSIONS

We have measured the average ACS of a PCB in a reverberation chamber and approximately matched it to the average ACS of a surrogate representative contents fabricated from RAM slabs arranged on a metal plate over the frequency range 2-20 GHz. The SE of an enclosure was then measured, also in a reverberation chamber, with either the real PCB or surrogate inside. Very good agreement was obtained between the SE in the two cases. The small difference could be explained as due to imperfect matching of the ACS of the surrogate. The approach presented forms the basis of an enclosure SE measurement methodology that takes account of the effect of the enclosure contents on the internal electromagnetic environment.

ACKNOWLEDGEMENT

This work was supported by Huawei Technologies Co. Ltd., Shenzhen, P. R. China under Contract YB2014090010.

REFERENCES

[1] A. C. Marvin and Y. Cui, "Towards evaluating the shielding of enclosures with contents at frequencies above 1 GHz", *IEEE International Symposium on Electromagnetic Compatibility*, Chicago, IL, pp. 200–205, 8-12 August, 2005.

[2] A. Lozano,M. P. Robinson, A. Díaz and J. V. Balbastre, "Evaluation and optimization of an equivalent model for printed circuit boards inside metallic enclosures", *Proceedings of the XXIX General Assembly of the International Union of Radio Science (URSI)*, Chicago, IL, Paper Number EBp6, 7-16 August, 2008.

[3] IEEE-STD 299.1, "Standard method for measuring the shielding effectiveness of enclosures and boxes having all dimensions between 0.1 m and 2 m", *Institute of Electrical and Electronics Engineers*, Piscataway, NJ, October 2013.

[4] D. A. Hill, M. T. Ma, A. R. Ondrejka, B. F. Riddle, M. L. Crawford and R. T. Johnk, "Aperture excitation of electrically large, lossy cavities", *IEEE Transactions on Electromagnetic Compatibility*, vol. 36, no. 3, pp. 169-178, August 1994.

[5] A. Gifuni, "Relation between the shielding effectiveness of an electrically large enclosure and the wall material under uniform and isotropic field conditions", *IEEE Transactions on Electromagnetic Compatibility*, vol. 55, no. 6, pp. 1354-1357, December 2013.

[6] I. D. Flintoft, S. J. Bale, S. L. Parker, A. C. Marvin, J. F. Dawson and M. P. Robinson, "On the measureable range of absorption cross-section in a reverberation chamber", *IEEE Transactions on Electromagnetic Compatibility*, accepted for publication.

[7] A. Gifuni, "On the measurement of the absorption cross section and material reflectivity in a reverberation chamber", *IEEE Transactions on Electromagnetic Compatibility*, vol. 51, no. 4, pp. 1047-1050, 2009.

[8] I. D. Flintoft, S. L. Parker, S. Bale, A. C. Marvin, J. F. Dawson and M. P. Robinson, "Measured average absorption cross-sections of printed circuit boards from 2 to 20 GHz", submitted to IEEE Transactions on Electromagnetic Compatibility.

[9] Emerson & Cuming, "Eccosorb LS", Technical Bulletin, Revision 5/11/07, URL: http://www.eccosorb.com/Collateral/Documents/English-US/LS.pdf.

[10] U. Carlberg, P.-S. Kildal, A. Wolfgang, O. Sotoudeh, and C. Orlenius, "Calculated and measured absorption cross sections of lossy objects in reverberation chamber", *IEEE Transactions on Electromagnetic Compatibility*, vol. 46, no. 2, pp. 146–154, May 2004.